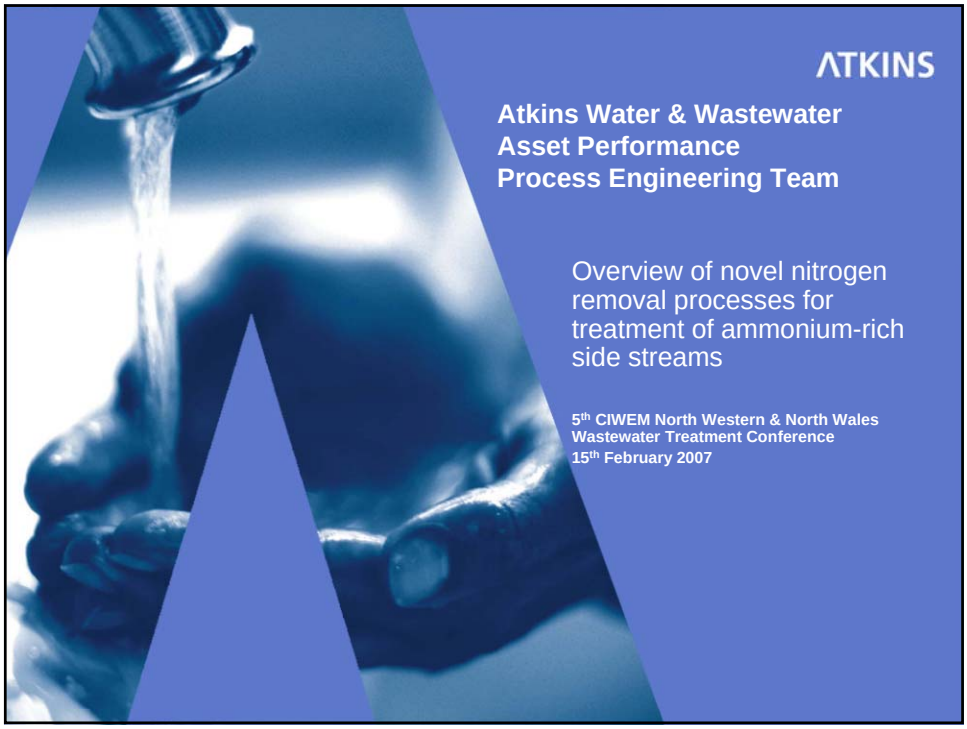

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Atkins Water & Wastewater
Asset Performance
Process Engineering Team

Overview of novel nitrogen removal processes for treatment of ammonium-rich side streams

5th CIWEM North Western & North Wales Wastewater Treatment Conference
15th February 2007

Plan of presentation

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- Background
- Nitrogen conversions
- Sharon process
- Anammox process
- Combined Sharon and Anammox processes
- Side stream treatment
- Anammox system characteristics for full-scale application
- Sharon system characteristics for full-scale application
- Research & process scale-up

2

Background

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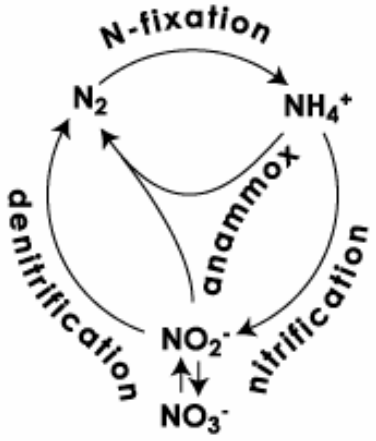
- The biological nitrogen cycle
- Human impact on the nitrogen cycle
- More stringent N effluent standards
- Anaerobic ammonium oxidation (Anammox)
- Application of the Anammox bacteria in the wastewater treatment – nitrogen removal from ammonium-rich streams

Three genera of Anammox bacteria:

- ***Brocadia***
  - ***Brocadia anammoxidans***
- ***Kuenenia***
  - ***Kuenenia stuttgartiensis***
- ***Scalindua***
  - ***Scalindua brodae***
  - ***Scalindua wagneri***
  - ***Scalindua sorokinii***



Source: www.anammox.com

Nitrogen conversions

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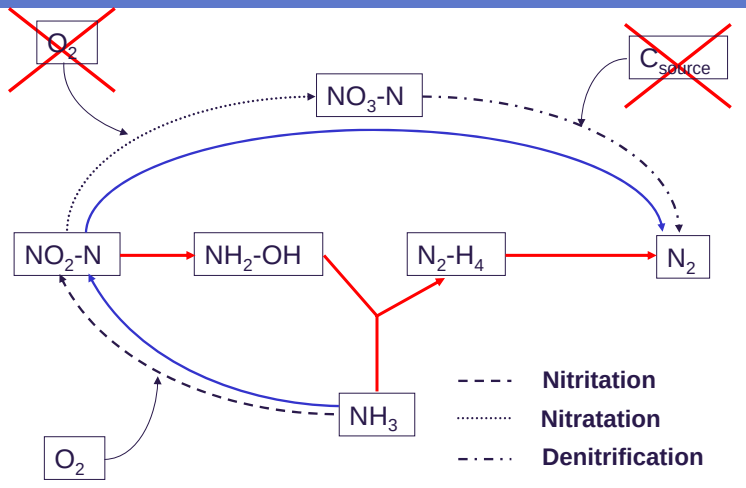
Save energy costs!

No addition of C source!



Nitrogen conversions

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SHARON = Single reactor system for High Ammonium Removal Over Nitrite:

- 1st step = oxidation of ammonia under aerobic conditions to nitrite nitrogen

$$NH_4^+ + 1.5\ O_2 \rightarrow NO_2^- + H_2O + 2\ H^+$$

- 2nd step = shortened denitrification process: nitrite nitrogen is reduced to nitrogen gas under anoxic conditions

$$NO_2^- + 0.5\ CH_3OH \rightarrow 0.5\ N_2 + 0.5\ CO_2 + 0.5\ H_2O + OH^-$$

ANAMMOX = Anaerobic Ammonium Oxidation:

$$NH_4^+ + NO_2^- \rightarrow N_2 + 2H_2O$$

CANON = Completely Autotrophic Nitrogen removal Over Nitrite

$$1\ NH_3 + 0.85\ O_2 \rightarrow 0.11\ NO_3^- + 0.44\ N_2 + 0.14\ H^+ + 1.43\ H_2O$$

5

Sharon process

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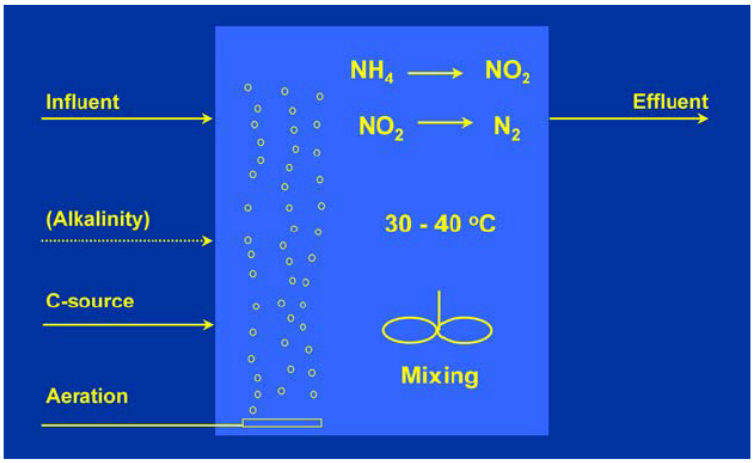

Schematic representation of SHARON

Source: www.grontmij.nl

6

Anammox process

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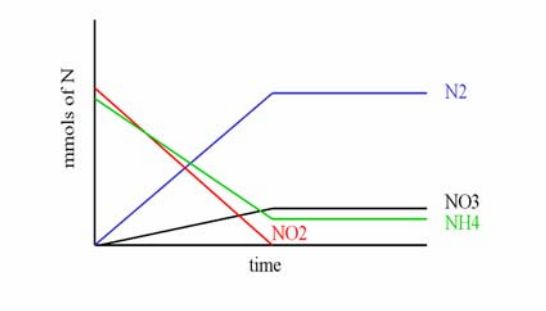
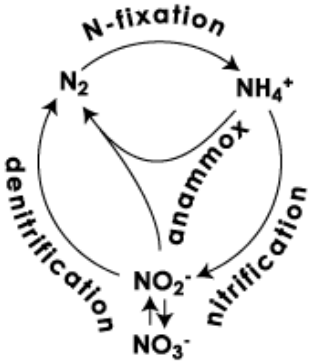
$NH_4^+ + NO_2^- \rightarrow N_2 + 2H_2O$





Source: www.anammox.com

7

Combined (Partial) Sharon & Anammox processes

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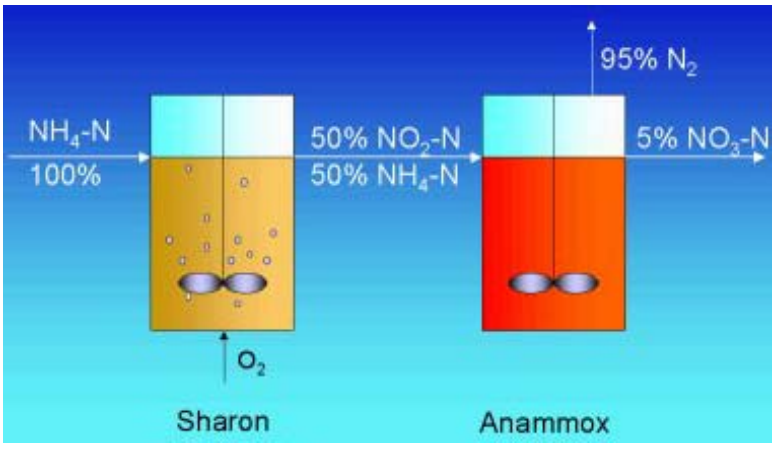

Source: STOWA webpage

8

Side stream treatment – digester supernatant

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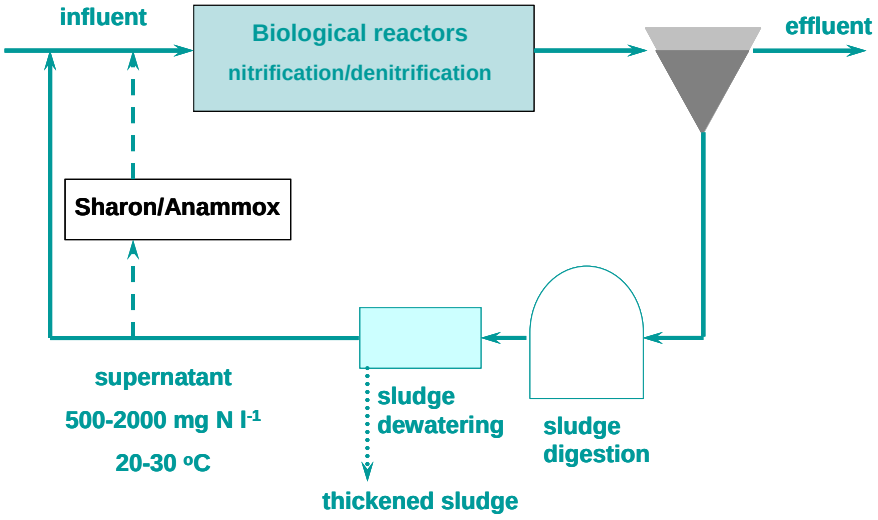

9

Anammox system characteristics for full-scale application

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- Side streams: digester supernatant, urine, leachates, poultry and piggery wastes thin fractions, sludge dryers and incineration liquors, industrial streams
- Compactness and low footprint
- Integration into existing wastewater treatment system
- Choice of reactor
- Type of biomass (immobilized cells, suspension or granular sludge)
- Anammox potential capacity: e.g. gas-lift reactor 8.9 kg N/m3 d (Sliekers et al., 2003)
- A cost estimate of 0.75 euro/ kg N removed (the Netherlands) for combined partial Sharon/ Anammox processes
- Process ”bottlenecks”
  - Anammox bacteria sensitivity: nitrite, methanol, oxygen
  - Anammox low doubling time 11 days
- Start-up period

10

Biofilm vs. granular sludge

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10 mm

Kaldnes rings

Anammox granules

11

Sharon (full) system characteristics for full-scale application

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- Nitrification and denitrification take place in a single reactor
- Short hydraulic retention time to enable *Nitrobacter* wash-out
- High process temperature (30 - 40°C) BUT additional heating is only required in wintertime for reject water treatment
- Intermittent aeration – oxic/anoxic cycle pattern
- 25% oxygen savings & 40% methanol savings & 40% less sludge production
- A cost estimate of 1.5 euro/ kg N removed (the Netherlands)
- Bottlenecks:
  - high effluent SS concentrations up to 100 mg/l
  - Careful pH control

12

Research & process scale-up

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SHARON

- The Netherlands: Rotterdam, Utrecht, Zwolle, Beverwijk, Garmerwolde and Den Haag (total capacity 2,740,000 PE)
- USA: New York (3,000,000 PE)
- Switzerland: Zurich (?)

ANAMMOX

- The Netherlands: Rotterdam
- Germany: Hattingen
- Sweden: Stockholm

13

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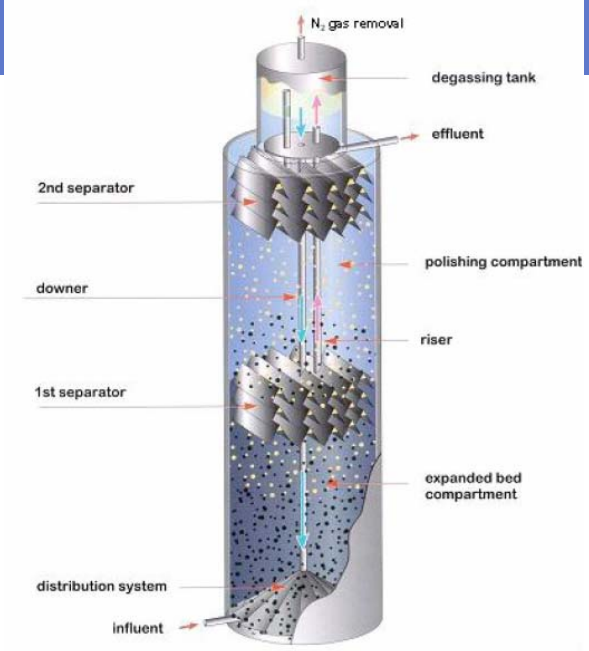
The first full-scale **Anammox reactor**, Rotterdam, the Netherlands.

It works at design load and removes over 500 kg N/day.

Photo: Paques BV

Source: anammox.com

14



Picture: Paques BV
Source: anammox.com

15

Anammox: AMX-820/CY3, pink
Eubacterial probe: CY5, purple

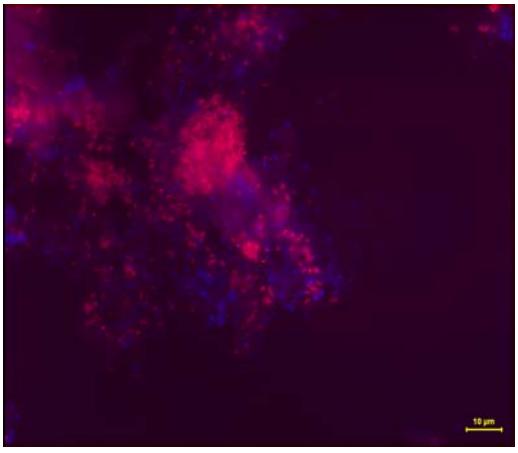


photo Wouter van der Star, Delft University of Technology, the Netherlands

Thank you for attention

Any questions?

luiza.gut@atkinsglobal.com

16

Sharon process – bacteria growth rates

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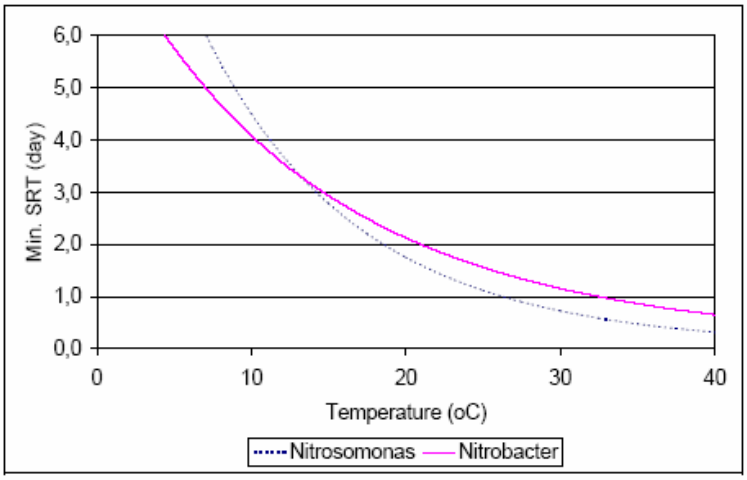

17

Conductivity as monitoring parameter

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Nitritation: $2NH_4^+ + 1.5O_2 + 2HCO_3^- \rightarrow NH_4^+ + NO_2^- + 2CO_2 + 3H_2O$

ions

Anammox: $NH_4^+ + NO_2^- \rightarrow N_2 + 2H_2O$

Decrease in conductivity

Total: $2NH_4^+ + 1.5O_2 + 2HCO_3^- \rightarrow N_2 + 2CO_2 + 5H_2O$

molecules

18

Results – Partial nitritation

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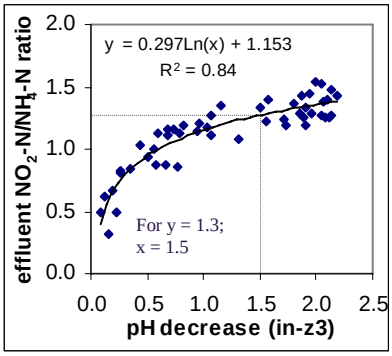
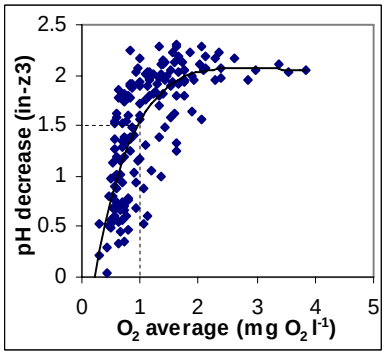


The pH decrease and the effluent NO_2-N/NH_4-N ratio in R1



The pH decrease and the average dissolved oxygen concentration in R1

19

Results – Anammox

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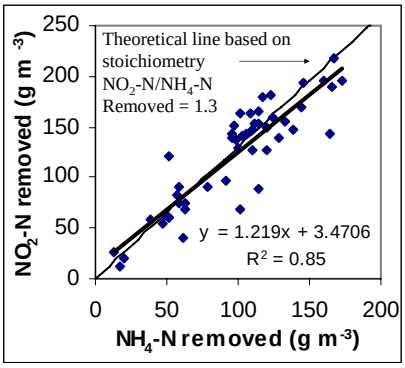
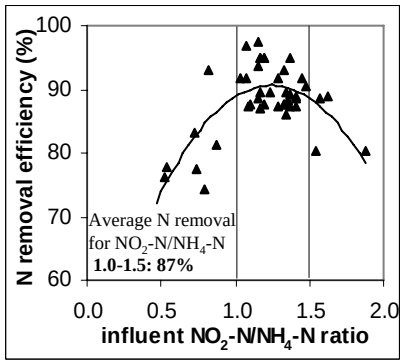


Removal of ammonium and nitrite nitrogen in R2



The influent NO_2-N/NH_4-N ratio and the nitrogen removal efficiency in R2

20